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Learning Factory platforms for advanced networked and service-based manufacturing systems and organizations
Part III – Freeware Collaborative Environment

Abstract
This paper presents a Learning Factory platform that is based on exploration of the freeware collaborative tools to address the education on advanced networked and service-based manufacturing systems such as social network-based manufacturing system. The paper presents (1) an architecture of learning factory with embedded freeware collaborative tools simulating the advanced networked and service-based manufacturing systems and organizations, and (2) elements of an application for manufacturing engineering course. The freeware-based Learning Factory platform, or environment, is oriented towards both internal and external learning and training, and for both communities, academe and industry and, especially, through their partnership. Also, the special feature of the platform is its "low-cost" allowing learning and training on advanced networked and service-based manufacturing systems in investment extensive regions and environment.

Keywords
Learning factory; Freeware collaborative environment; Networked manufacturing systems; Service-based manufacturing systems; Engineering education; Project-led education.

1. Introduction

Advanced networked and service-based manufacturing systems and organizations are emerging forms expected to provide a higher levels of sustainability in terms of economic, environmental and social sustainability. These systems are not yet considered as regular parts of engineering and management education. However, there are growing needs for their fast adoption and training on their operation and management.

The concept of Learning Factory is one of modern advanced instruments for faster adoption and training of different manufacturing systems paradigms that integrates "… design, manufacturing and business realities into engineering education. This is accomplished by providing a state-of-the-art, hands-on active learning laboratory, a practice-based curriculum, and real (industry-driven) projects." (Lamancusa & Simpson, 2004).

It could be said that "the Learning Factory is a paradigm shift to industry-partnered, interdisciplinary, real-world problem solving in engineering education" (Lamancusa et al. 2008). The fact that Learning Factory put university and enterprises in real time interactive connection makes it, additionally, an instrument for enhancement of university-enterprises interrelationship in many dimensions.

A general model of Learning Factory, representing the "industry-partnered, interdisciplinary, real-world problem solving in engineering education", in an informal representation, is given in Figure 1.

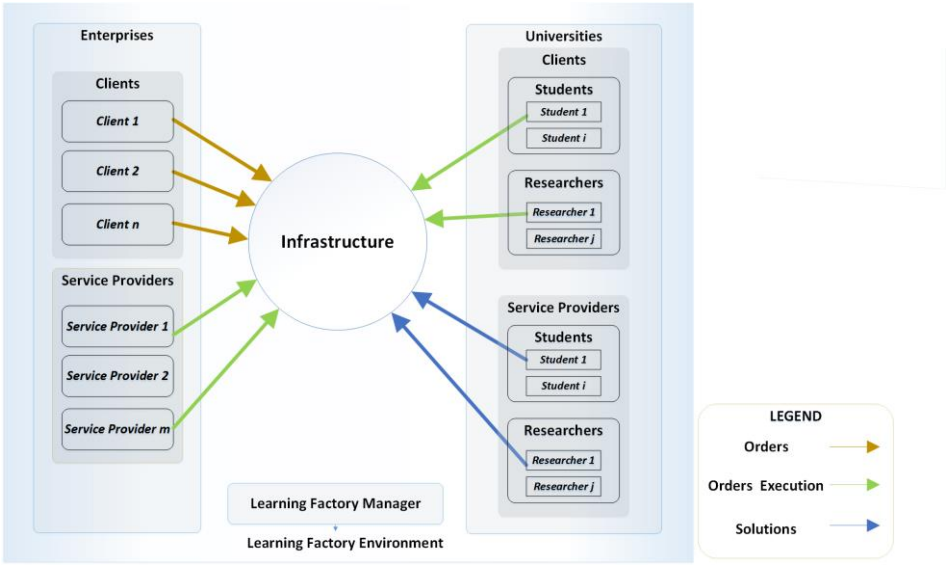

Figure 1. Informal view of Learning Factory environment

Implementation of the Learning Factory concept spans from very traditional methods to use of the most advanced technologies. Obviously, the Learning Factory for advanced networked and service-based manufacturing systems and organizations should employ an advanced Information and Communication Technologies (ICT)-based platform, organization that simulate large networks of manufacturing agents and manufacturing services exchange in high volume.

In this paper a Learning Factory platform is presented based on exploration of freeware collaborative tools for learning in advanced networked and service-based manufacturing systems and organizations.

In the first part of the paper, an architecture of learning factory with embedded freeware collaborative tools simulating the advanced networked and service-based manufacturing systems and organizations is introduced, and, in the second part, elements of an application for manufacturing engineering course are presented.

2. Advanced networked manufacturing systems and service-based manufacturing systems

The common properties of advanced networking forms are:

(1) all of them are networked systems, integrating large numbers of “nodes”,

(2) all of them have extremely high capacity of changing the way of work and doing business, whether for individuals or for enterprise, and

(3) all of them are highly scalable systems simply because these systems ‘‘are not bound to a predefined size, so that the underlying coordination mechanism has to be highly scalable’’ (Obreiter & Graf, 2002).

Concerning the Learning factory for advanced networked and service-based manufacturing systems and organizations objectives, the property (1) assures that a (large) number of enterprises could be linked with higher education institutions and among themselves through the common Learning Factory environment. Considering that the participants of the Learning Factory are individual students, micro-enterprises, freelancers, individual entrepreneurs and one-person enterprises, the size of the network can easily achieve the large size.

The property (2) is a result of independency of each participant in the network and free will to group with other participants in a specific joint venture on a temporary base, which means that these advanced networking forms has capacity of self-organization. The self-organization by itself is a guarantee for maximizing effectiveness and efficiency of the organization.

The property (2) is a consequence of the network openness in terms of free joining and leaving the network, which results is in network scaling.

Some of the well-known advanced networking forms are social networks, crowdsourcing, Web 1.0 to 4.0, internet of things, ubiquitous and cloud technologies, cyber-physical systems. While the social networks, crowdsourcing, Web 1.0 to 4.0 are networks of human participants, the internet of things, ubiquitous and cloud technologies, cyber-physical systems are network of artefacts, i.e., products, equipment, components, and "things".

These forms advanced networked manufacturing systems are necessarily type of service-based systems. Service-based manufacturing systems could be defined through analogy with Product-service systems, which, the product-service system, is characterized by Mont (2002) as:

- The sale of the use of the product instead of the product itself;
- The change to a 'leasing society';
- The substitution of goods by means of service machines;
- A repair-society instead of a throw-away society;
- The change in consumer attitudes from sales to service orientation.

Interpreting the above product-service system features for service-based manufacturing systems, it means that the task realization will be sought to be realized as a service by an external provider (member of the network), instead by an internal provider (employee). The difference is that the external provider is paid just for the service provided and the time spent for the service, while the internal provided is paid for the time working in the company, independently of the tasks he is realizing. The tasks to be contracted as a service could be very complex or primitive.

3. Learning Factory for collaborative, advanced networked and service-based manufacturing system

Learning Factory for collaborative, advanced networked and service-based manufacturing system must have the properties that simulates the principle of the service-based manufacturing systems with embedded collaborative tools.

A global view of Learning Factory environment for advanced networked and service-based manufacturing systems and organizations is presented on Figure 2.

The difference from the general model of Learning Factory is that all tasks by clients (companies that participate in learning factory network, or teachers or students or researcher that perform as virtual clients) are published through the internet-based learning factory platform, as on the Market (the student group of researcher group that participate in the course), and the service providers (students or researcher that participate in the course) concur to get the "contract" (task or project work assignment) to realize the tasks (project work).

4. Learning Factory freeware-based collaborative environment architecture

The Learning Factory platform architecture is a projection of the supporting architecture for the learning factory for advanced networked and service-based manufacturing systems and organizations in which the manufacturing corresponds functionally to a service system, integrating services for tasks (project works) publishing, communication system for negotiation between the "clients" and the "service providers", system for project management (tasks assignments and monitoring of the task execution), collaborative development of tasks documentation, shared memory space.

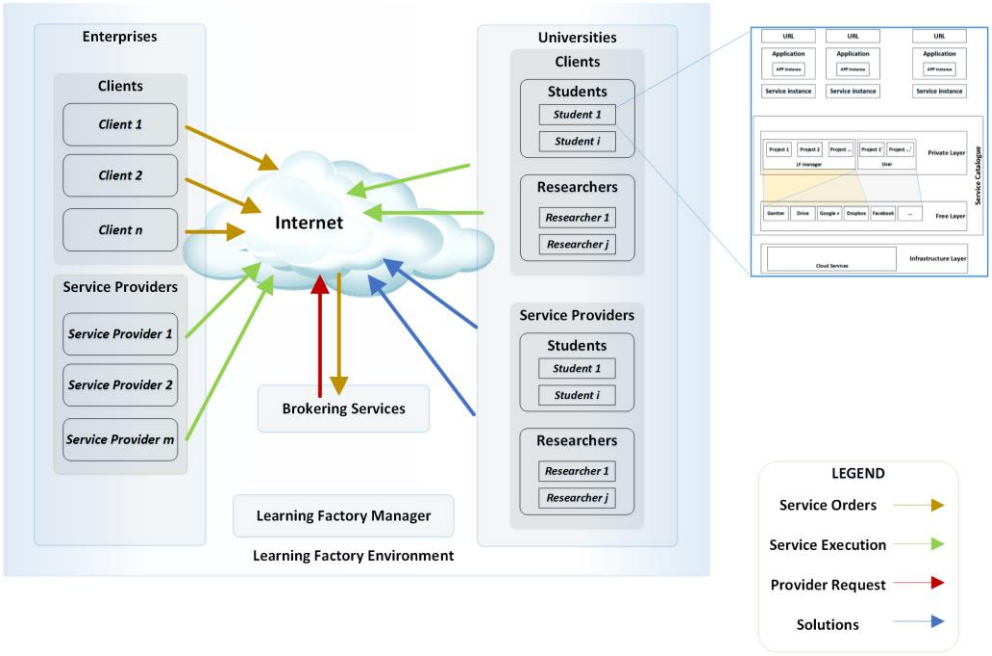

Figure 2. Global view of Learning Factory environment for advanced networked and service-based manufacturing systems and organizations

All these functionalities could be supported by specific private and/or commercial applications. However, these functionalities could be supported also by available freeware applications.

The learning factory environment for advanced networked and service-based manufacturing systems and organizations is based on a supporting Information and Communication Technology (ICT) platform that should embed applications, as services, for the abovementioned learning factory functionalities. The concept of freeware based learning factory environment is a special case that exploit available freeware applications.

There is a number of freeware applications available with different capacities and other different conditions of use. An architecture of the Learning Factory freeware-based collaborative environment is presented on Figure 3 that embeds the following freeware applications (Table 1):

Table 1. Services and tools

Services	Tool
Tasks (project works) publishing	Google +
Communication system for negotiation between the "clients" and the "service providers"	Google +
System for project management (tasks assignments and monitoring of the task execution)	Gantter
Collaborative development of tasks documentation	Google Drive
Shared memory space	Dropbox

5. An application for manufacturing engineering course

The presented Learning Factory concept and the freeware based platform was implemented and used for the curricular units of Computer Assisted Design/Computer Assisted Process Plan (CAD/CAPP) and Computer Assisted Manufacturing (CAM) of the 4th year of the Industrial Engineering and Management master course of University of Minho.

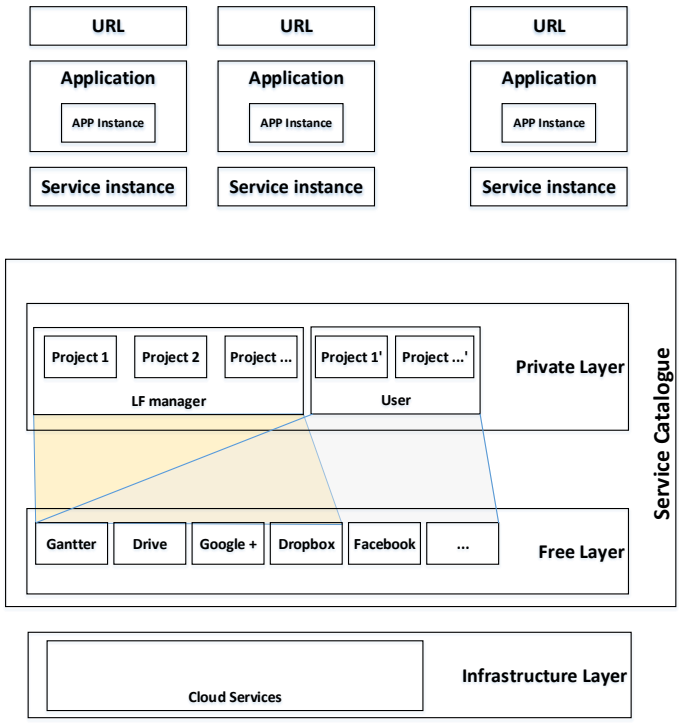

Figure 3. Freeware-based Collaborative Environment Architecture

This was the first time that this experience occurred in the course. A total of 43 students participated in the project where 6 of them were defined as "clients" (called "project coordinators") and the remaining 37 students were assigned as "service providers" (called "resources") of two types, namely, as individual resources and group resources. Each one of those 37 remaining students were assigned as an individual resource and were also organized in 6 working groups (in accordance with traditional PLE methodology), and each working group were assigned as a group resource type. So, the total number of participants were 43 students but in total, the "manufacturing network" to realize the assigned projects consisted of 49 actors, i.e. 6 project coordinators (C1, C2, etc.), 37 individual resources (R1, R2, etc.) and 6 working groups (G1, G2, etc.).

Every coordinator was responsible for creating one final document for the project evaluation in Google Drive, which promotes a collaborative environment since it allows viewing and editing documents by multiple actors at the same time (Figure 4).

Each assigned projects to be realized were divided in 95 tasks that were launched by the project coordinators to all actors simultaneously, using Google +, and these were assigned based on the negotiation between the coordinator and the candidate resource. Project coordinators used the *Gantter* application (Figure 5) for *Google Drive* to assign tasks to the resources, to monitor and manage their realization (precedencies, deadlines and costs). All participants were using all tools referred above intensively, as well as, other tools such as Facebook, for their "private" communication and share of information.

6. Conclusions

The conceived Learning Factory freeware-based collaborative environment platform demonstrated its effectiveness and capacities in real life applications, providing an excellent base for further development of the concept and its wider use, especially including companies in the teaching courses in accordance with the learning factory concept.

The special achievement of the Learning Factory freeware-based collaborative environment application for teaching and training of advanced networked and service-based manufacturing systems was that the students had experienced of a near real life scenario of the service-based manufacturing systems and not only the narrative description of what does it mean.

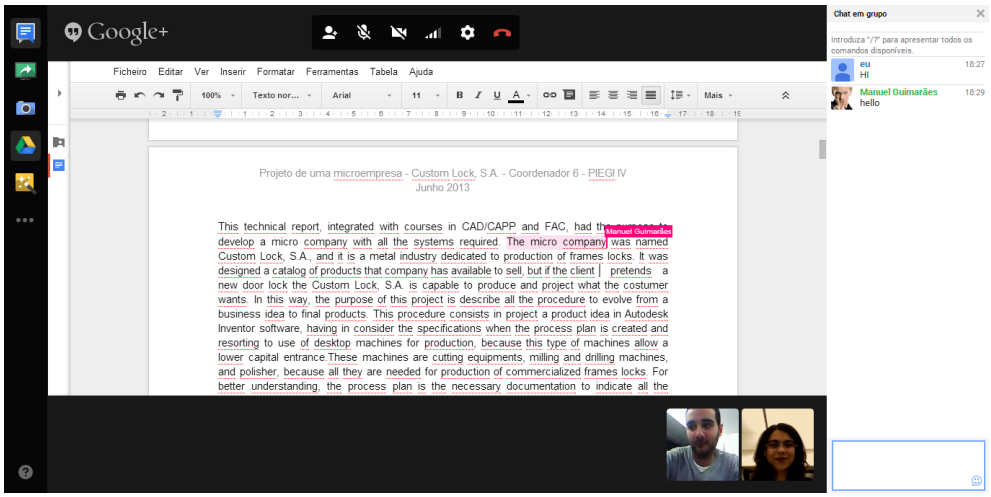

Figure 4. Combined use of Google + and Google Drive

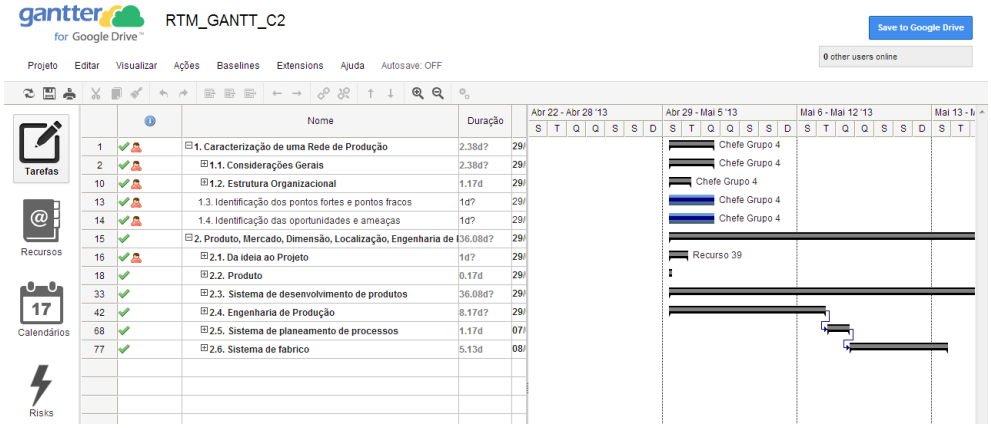

Figure 5. *Gantter* for Google Drive

The future work will be developed in several directions such as further development of the concept of Learning Factory for advanced networked and service-based manufacturing systems and organizations, development of the ICT platform, and improvement of the teaching course design, that is of the teaching methodology and the course contents.

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References

Lamancusa, J. S. and Simpson, T. W., (2004). The Learning Factory - 10 Years of Impact at Penn State, *International Conference on Engineering Education*, Gainesville, FL, iNEER, October 16-21, pp. 1-8.

Lamancusa, J. S., Zayas, J. L., Soyster, A. L., Morell, L., and Jorgensen, J., (2008). The Learning Factory: Industry-Partnered Active Learning. *Journal of Engineering Education*; pp. 5-11.

Obreiter P, Graf G (2002) Towards Scalability in Tuple Spaces. *Proceedings of the 2002 ACM Symposium on Applied Computing*, ACM, Madrid, Spain344–350ISBN: 1-58113-445-2.

Mont, O. K. (2002). Clarifying the concept of product–service system. *Journal of cleaner production*, *10*(3), 237-245.